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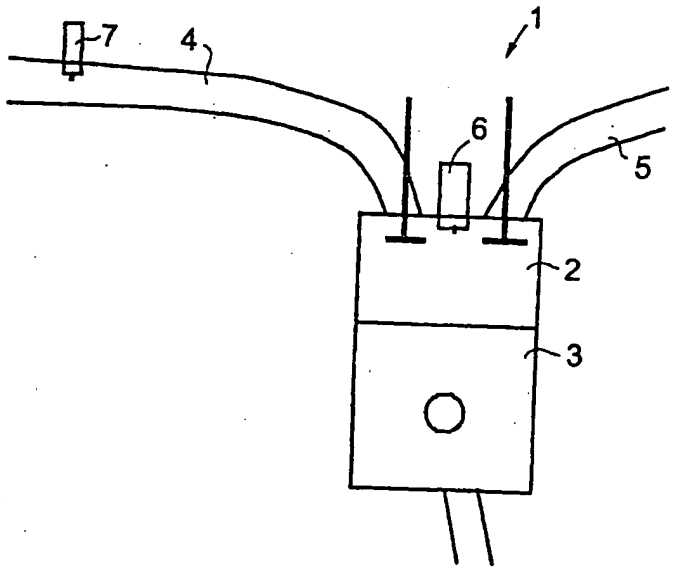

(57) Abstract

A method for fuel injection in a combustion engine of piston and cylinder type with compression ignition (1), whereby a controlled quantity of fuel is supplied to the combustion chamber (2) for each working cycle, is distinguished by the fact that a first "shot" of said controlled fuel quantity is supplied (7) during the air inlet phase (4) in order to establish a homogeneous fuel/air mixture, and that a second "shot" is supplied (6) directly to the combustion chamber (2) as injected fuel. The invention also relates to a combustion chamber operating according to the method.

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Method for fuel injection in an internal combustion engine and internal combustion engine

Field of the invention

The present invention relates to a method for fuel injection in a combustion engine of piston and cylinder type in accordance with the preamble to patent claim 1, and to a combustion engine in accordance with the preamble to patent claim 6.

State of the art

The problem of high NO_x emissions from conventional diesel engines arises from very high combustion temperatures in limited portions of the cylinder at the time of ignition, due to combustion taking place along a defined combustion front with low λ numbers (air/fuel ratios).

The various arrangements which have been adopted with a view to preventing these emission problems of diesel engines include combustion engines which are known by the designation ATAC (Active Thermo Atmospheric Combustion) and may popularly be said to be a combination of a diesel engine and an Otto engine. In their case, a premixed fuel/air mixture is introduced into the cylinder and is ignited by compression when the working piston is in the vicinity of its top dead centre position in the ignition phase. ATAC engines afford considerable advantages, particularly in the form of small or no NO_x discharges and high efficiency which approaches that of diesel engines. ATAC engines overcome the problem by using a substantially leaner mixture (with high λ number) resulting in lower combustion temperatures due to combustion being initiated substantially simultaneously within widespread regions of the combustion chamber. The overall result is a more uniform temperature distribution.

In combustion engines of the kind which employs combustion of a homogeneous premixed fuel/air mixture, it has been found possible to overcome the emission problem with regard to harmful pollutants. However, this type of engine suffers from a number of disadvantages, including a narrow load range. This means that acceptable operation

depends on ignition taking place in a limited situation close to the top dead centre position (TDC) of the working piston. The commencement of combustion depends on several parameters, but primarily on the temperature in the combustion chamber. As this temperature itself depends to a large extent on the charging pressure and the load, the point in time at which the ignition of the gas mass commences will vary substantially. This means poor engine efficiency and that the thermal loading on the engine will be large if ignition takes place too early, which tends to occur at high loads. If ignition is late, the efficiency will likewise be poor and the combustion incomplete, resulting in high HC (hydrocarbon) emissions, which tends to occur at low loads. A further problem is that the ignition commencement point is not stable. An example is where the ignition commencement point is in the region around the dead centre position of the working piston. An infinitesimal change in the ignition commencement time relative earlier ignition towards TDC causes an infinitesimal increase in the engine's thermal loading, resulting in higher temperature during the next cycle, and so on, thereby driving the ignition commencement point still earlier relative to TDC in an escalating pattern with harmful consequences.

Object and most important characteristics of the invention

An object of the present invention is to indicate a method and a combustion engine which eliminate or at least reduce the disadvantages of the state of the art.

This object is achieved according to the invention by a method for fuel injection of the kind mentioned in the introduction in accordance with the characterising part of patent claim 1 and by designing the combustion engine according to the features in the characterising part of patent claim 6.

The advantages of combustion engines of the kind which employs combustion of a homogeneous premixed fuel/air mixture are thus maintained but the disadvantages of such engines are avoided. A first quantity of the fuel which is to be involved in the combustion process being introduced as early as the air inlet phase in order to establish a homogeneous fuel/air mixture, accompanied by the usual diesel engine practice that the remainder of the fuel which is to be involved in the combustion process is directly

injected into the cylinder for conventional initiation of its combustion, means that the first homogeneously mixed quantity serves as a preheater and ignition initiator for the quantity of fuel injected subsequently.

The principle of the invention may be applied in all diesel engines and with different diesel fuels. In particular, the invention may be applied to operation with fuels that do not readily ignite, such as ethanol and methanol. In conventional diesel engines run on ethanol, it may in certain operating situations be possible to run the engine on pure ethanol, e.g. at high loads. At lower loads, however, problems arise with operating with pure ethanol fuel, so a so-called ignition improver, e.g. a nitrated compound or, for example, polyethyleneglycol, has to be mixed into the fuel. However, ignition improving additives in the fuel entail not only increased costs but also, in many cases, adverse affects on the engine. Such additives do in particular involve risk of affecting the lubricating oil and of deposits in injection pumps and ducts, as well as problems with oil cleaning equipment.

The invention makes it possible, without adding an ignition improver, to run diesel engines on fuels which do not readily ignite, such as ethanol, since the homogeneously mixed first "shot" of fuel will in practice act as an ignition improver and also, as above, as a preheater, so that the injected second "shot" ignites reliably at the desired time.

In diesel engines with more conventional fuels, such as diesel oil, the invention is particularly valuable during cold starts but is also applicable in other operating situations.

Engine operation may be optimised by varying the ratio between the first and second fuel shots. It may be mentioned, by way of example, that in normal running at full load it may be possible to supply a small first shot of fuel, or even no fuel at all, in order to establish a homogeneous fuel mixture, while at lower loads it is desirable to have a larger shot of established homogeneous fuel/air mixture. As the previously mentioned ATAC combustion produces very low NO_x emissions, it may be advantageous to arrange that the fuel supplied at no-load and low loads should respectively consist exclusively or largely of the first shot of fuel which is supplied in order to establish a homogeneous fuel/air mixture. Good results may in principle also be achieved if the same quantity as that

constituting the first shot is used during the whole period of operation. The invention is thus not limited to improving the conditions for the normal combustion of directly injected fuel.

It is preferred that the first shot be supplied already in the air inlet pipe, as this arrangement ensures that the fuel/air mixture supplied to the cylinder is advantageously homogenised. Further advantages are achieved by various aspects of the invention and will be indicated by the following detailed description.

Brief description of drawings

The invention will now be described in more detail on the basis of an embodiment with reference to the attached drawings, in which:

Fig.1 depicts schematically a combustion engine equipped according to the invention,

Fig.2 depicts schematically a control system used according to the invention, and

Fig.3 shows a diagram of the combustion pressure and the movement of the injection valve as a function of the crank angle of a combustion engine according to the invention.

Description of an embodiment

The combustion engine 1 depicted schematically in Fig.1 is of diesel type and incorporates a cylinder space 2 and a piston 3 which is movable in the cylinder. The cylinder space 2 has leading into it an inlet duct 4 and leading out of it an outlet duct 5, each of them provided conventionally with appropriate valves. In the usual manner, at least one injection nozzle 6 is installed in the cylinder head for direct injection of fuel into the fuel chamber.

According to the invention, there is in addition a second fuel nozzle 7 installed in the inlet duct 4 so that the fuel supplied via this latter nozzle during the induction phase creates the possibility of establishing a homogeneous fuel/air mixture.

The control system in Fig.2 incorporates a control unit 8 which is supplied with signals 9 representing engine operating parameters such as engine speed, load, engine temperature,

accelerator pedal position, exhaust composition etc. The control unit 8 is designed to control an injection valve 10 in order thereby to control the fuel quantity injected via the injection nozzle 6. The control unit 8 is also designed to control a second fuel valve 11 in order to control the supply of fuel to the second fuel nozzle 7. The control unit is preferably programmed to optimise the ratio between the fuel quantities injected via the nozzles 6 and 7, the total quantity of fuel injected and, where applicable, the times when the respective injections take place relative to the engine's crank angle.

The diagram shown in Fig.3 thus illustrates the cylinder pressure as a function of the crank angle and A_K denotes the cylinder pressure generated by the actual piston movement. The deviation of curve A from that line denotes the pressure increase due to fuel combustion. The first deviation from curve A_K is at point 12 and ΔP_1 denotes the pressure increase due to combustion of the first shot of fuel injected via the nozzle 7. Point 13 denotes a deviation from this curve A_F and is the point where fuel injected via the nozzle 6 also becomes involved in the combustion process. The result is a pressure difference ΔP_2. The invention thus achieves a first pressure increase ΔP_1 due to the combustion of the homogeneous fuel/air mixture and a corresponding temperature increase in the cylinder space, which temperature increase also causes reliable ignition of conventionally injected fuel at an acceptable time, and it may in principle be said that the ignition of this latter fuel is shifted to an earlier time. In such situations as cold starts, the combustion process may otherwise commence only long after the top dead centre point.

The bottom curve in Fig.3 relates only to the crank angle scale of the diagram and indicates the injection valve's opening 14 and closing 15, between which the other shot of fuel is injected via the nozzle 6.

The invention may be varied within the scope of the claims, and in particular the ratio between the various "shots" referred to above may be adapted to cater for a variety of operating situations. It is nevertheless possible in principle to run with a fixed "first fuel quantity" throughout the operating range, in which case this quantity corresponds to the "no-load quantity", which is normally equivalent to about 5-10% of the "full-load quantity".

It is also possible to arrange the positioning and number of the injection nozzles according to the conditions prevailing in present-day engines. The configuration and positioning of the nozzle 6 and the relating fuel circuit may be conventional, while the circuit pertaining to the nozzle 7 may take the form of a very simple injection arrangement.

It is also possible to supply a variety of fuels, which differ in how readily they ignite, to form the respective first and second "shots", while at the same time operation may be further optimised for various operating situations such as starting, cold starting, low load, medium-high load, high load.

Experiments conducted with an engine operating according to the invention indicate that NO_x and particle discharges will be lower than those from conventional diesel engines run on methanol fuel containing ignition improvers. Some reduction in fuel consumption may also be expected.

It is preferred that the first "shot" be already supplied to the inlet air in the inlet line, as in the embodiment described, thereby ensuring homogenisation of the mixture, but it may also be supplied directly to the cylinder during the air inlet phase. Using a so-called "common rail" injection system for the injector 6 makes it possible to achieve a homogeneous mixture by means of an extra injection at the appropriate time. The spray nozzle 7 may then be omitted. Such cases afford the advantage of being able to use the same injection nozzle(s), although a controllable injection system has to be used. It may also be conceivable to use two different sprays in the cylinder, one of them to supply the first "shot", the other to supply the second.

Patent claims

1. Method for fuel injection in a four-stroke combustion engine of piston and cylinder type with compression ignition (1), whereby a controlled quantity of fuel is supplied to the combustion chamber (2) for each working cycle, **characterised in** that a first "shot" of said controlled fuel quantity is supplied during an air inlet phase in order to establish a homogeneous fuel/air mixture, and that a second "shot" is supplied (6) to the combustion chamber (2) as injected fuel for conventional initiation of ignition.

2. Method according to claim 1, **characterised in** that the first "shot" of said controlled fuel quantity is supplied (7) to the inlet air (4) before the combustion chamber (2).

3. Method according to claim 1 or 2, **characterised in** that the ratio between the first and second "shots" is controlled on the basis of operating parameters (9) such as engine speed, load, engine temperature, accelerator pedal position and/or exhaust composition.

4. Method according to claim 1, 2 or 3, **characterised in** that the ratio between the first and second "shots" is kept at about 1/20 to 1/10.

5. Method according to any one of the foregoing claims, **characterised in** that ethanol, methanol or diesel oil is used as fuel.

6. Combustion engine of piston and cylinder type with compression ignition (1), incorporating devices for supplying a controlled fuel quantity to the combustion chamber for each working cycle, **characterised in** that it incorporates first devices (7,11) for supplying a first "shot" of said controlled fuel quantity during an air inlet phase in order to establish a homogeneous fuel/air mixture, and second devices (6,10) for supplying a second "shot" directly into the combustion chamber (2) as injected fuel at the time for conventional initiation of ignition.

7. Arrangement according to claim 6, **characterised in** that the first "shot" of said controlled fuel quantity is arranged to be supplied to the inlet air (4) before the combustion chamber (2).

8. Arrangement according to claim 6 or 7, **characterised in** that said first device includes a fuel nozzle (7) delivering into an inlet duct (4) leading to the cylinder.

9. Arrangement according to claim 6, 7 or 8, **characterised by** a control unit (8) which, on the basis of operating parameters (9), is arranged to control the injection.

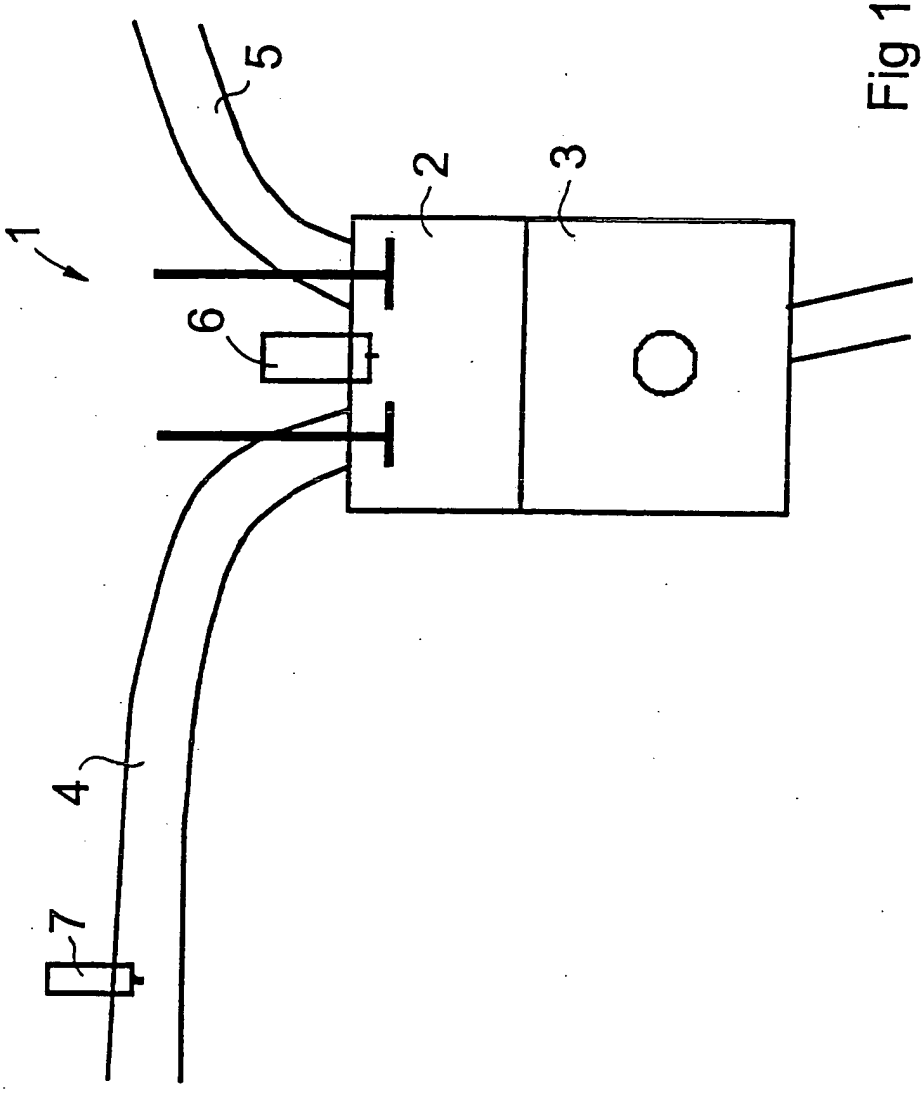

Fig 1

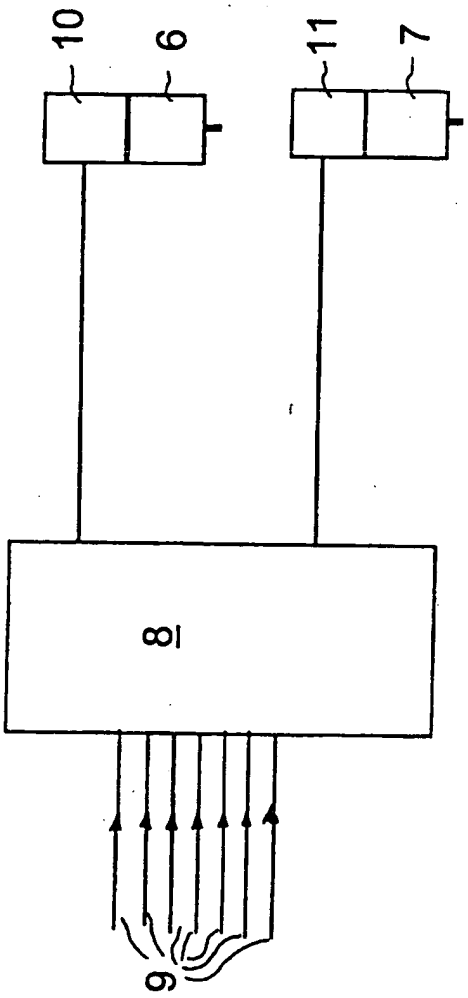

Fig 2

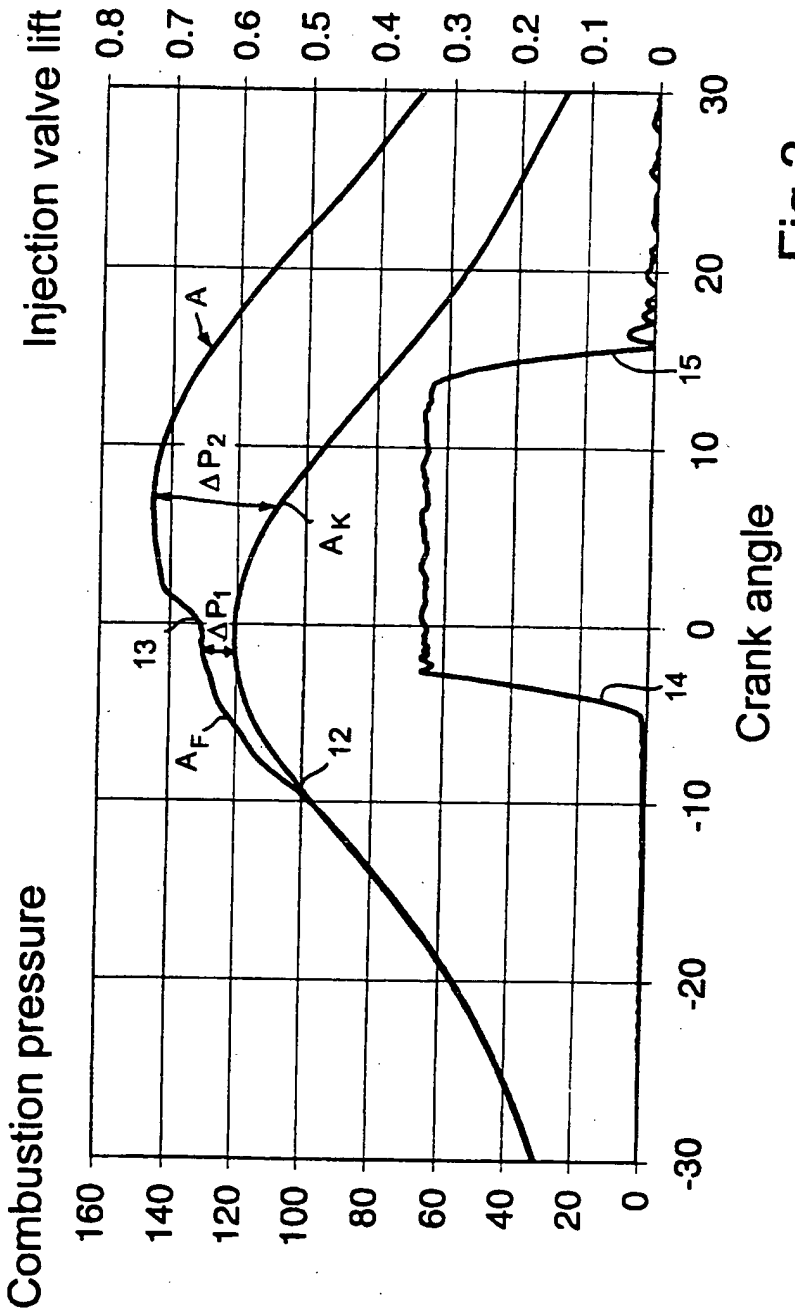
Combustion pressure
Injection valve lift
Crank angle
160
140
120
100
80
60
40
20
0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-30
-20
-10
0
10
20
30
A
ΔP_2
A_K
ΔP_1
A_F
12
13
14
15

Fig 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/00660

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F02B 1/12, F02B 7/00
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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 699512 A (ERLING POPPE), 11 November 1953 (11.11.53), page 1, line 38 - line 52; page 1, line 81 - line 95, figures 1-3	1-9
X	DE 19519663 A1 (DAIMLER-BENZ AKTIENGESELLSCHAFT), 15 May 1996 (15.05.96), column 2, line 30 - column 3, line 26, figures 1,2	1-9
X	US 4572133 A (BAGO), 25 February 1986 (25.02.86), figures 1,2, abstract	1-9

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 June 2000	2000 -07- 25
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Information on patent family members

02/12/99

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PCT/SE 00/00660

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 699512 A	11/11/53	NONE	
DE 19519663 A1	15/05/96	NONE	
US 4572133 A	25/02/86	NONE	